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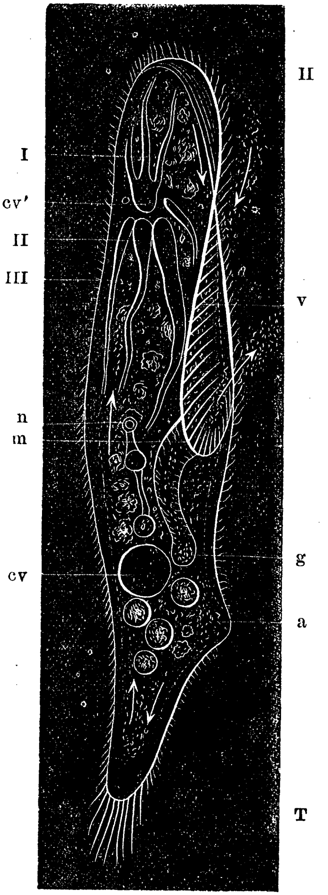
LIFE HISTORIES OF THE PROTOZOA AND SPONGES.

BY A. S. PACKARD, JR.

VII. THE INFUSORIA (CILIATA).

Fig. 29.



Paramecium.

Though the term Infusoria has usually been applied to nearly all the Protozoa provided with cilia or flagella, it is now restricted to the highest division of the Protozoa. Instead of an attempt to define the group, the following brief description of some of the well-known forms will perhaps best show how they differ from the Flagellata, with which they are most apt to be confounded.

One of the simplest and most abundant forms is Paramecium. The accompanying figure (29), copied from Clark's "Mind in Nature," represents *Paramecium caudatum*, of Ehrenberg.[1] This animalcule is a mass of protoplasm, representing, perhaps, a cell. In the body-mass are excavated a mouth and a throat leading to a so-called stomach or digestive cavity. Two hollows in the body form the contractile vesicles, and another cavity forms the reproductive organ. Prolongations of the body-mass form the cilia, which characterize the Infusoria and give their name, Ciliata. No specialized tissues composed of cells exist in these organisms, and they are regarded as on the whole representing a single cell. Some authors, as Claparède, regard them as composed of several cells, but the whole animal, though performing functions nearly as complicated as those of sponges, low worms and radiates which have bodies composed of many cells, should be regarded as made up of indifferent or unorganized sarcode or protoplasm, somewhat like that of the bodies of the embryos of the higher animals in their earliest stages.

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[1] Fig. 29. A view from the dorsal side, magnified 340 diameters. H, the head: T. the tail; *m*, the mouth; *m* to *g*, the throat; *a*, the posterior opening of the digestive cavity;

Paramecium has an elongated, oval body "with one end (H) flattened out broader than the other, and twisted about one-third way round, so that the flattened part resembles a very long figure 8." In this form, as in Stentor (Fig. 30), as Clark remarks, "we have the mouth at the bottom of a broad notch or incurvation, and the contractile vesicle on the opposite side, next the convex back, whilst the general cavity of the body lies between these two." The arrows in the figure represent the course of the particles of indigo with which Clark fed his specimens, "as they are whirled along, by the large vibrating cilia (*v*) of the edge of the disk, against the vestibule of the mouth." During the circuit the food is digested, a mass of *rejectamenta* is formed near the protuberance, *a*, which has appeared a short time before. This finally opens, allows the rejected matter to pass out and then closes over, leaving no trace of an outlet. This and other Infusoria seem, then, to have a definite digestive tract, hollowed out of the parenchyma of the body.

"The system," says Clark, "which is analogous to the blood circulation of the higher animals, is represented in Paramecium by two contractile vesicles (*cv*, *cv*^{1}, I, II, III), both of which have a degree of complication which, perhaps, exceeds that of any other similar organ" in these animals. When fully expanded they appear round, as at *cv;* but when contracted they appear, observes Clark, as "fine radiating streaks, and as the main portion lessens they gradually broaden and swell until the former is emptied and nearly invisible, and they are extended over half the length of the body. In this condition they might be compared to the arterial vessels of the more elevated classes of animals, but they would at the same time represent the veins, since they serve at the next moment to return the fluid to the main reservoir again, which is effected in this very remarkable way." The contents of these vesicles is a clear fluid.

The reproductive organ in Paramecium is a small tube (*n*), only seen at the reproductive period when the eggs (*n*) are fully grown.

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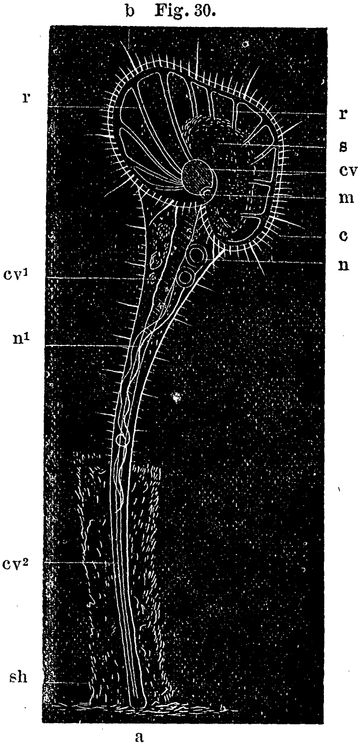
cv^1, the anterior and *cv*. posterior contractile vesicles; I, II, III, the radiating canals of *cv*^{1}; *n*, the reproductive organ; *v*, the large vibrating cilia at the edge of the vestibule. —After H. J. Clark.

Clark says that the eggs are arranged in it "in a single line, one after the other, at varying distances." It usually lies in the midst of the body, and extends from one-half to two-thirds of the length of the animal. "According to Balbiani's observations upon a closely allied species, when the eggs are laid they pass out from the ovary through an aperture near the mouth" (Clark).

Fig. 30.



Trumpet Animalcule.

In the Trumpet animalcule (Fig. 30, *Stentor polymorphus* of Ehrenberg, after Clark[2]) we have a higher grade of development than in Paramecium, the animalcule attaching itself at one end, and building up a slight tube in which it contracts when disturbed; an anticipation in nature of the worm in its tube. Prof. Clark has studied in this animalcule certain circular bands within the edge of the disk, from which arise twelve very thin stripes (*rr*) which converge towards the mouth (*m*). These bands are evidently, he says, in close relation with the mouth and cilia, the most active organs of the animal, and he concludes that it is a nervous system.

The most complicated form of all among the Infusoria is the Vorticella, or bell-shaped animalcule. These forms are very common on submerged plants and leaves, appearing to the naked eye like mould. Their motions, as they suddenly contract and then shoot out their bell, mounted on a long stalk, are very interesting. They form the most available and attractive infusoria for study and amusement. The throat is quite distinct, while the nucleus is the most conspicuous organ of the body. The digestive cavity is "one vast hollow," in which the whole mass of food revolves in a determinate channel (Clark). In fact, so highly developed are these Infusoria that they seem to anticipate certain low worms to which they bear a certain resemblance, and indicate that the worms may have sprung either from the Infusoria or early organisms like them.

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[2] "*Stentor polymorphus*, magnified 130 diameters, expanded and bent slightly over towards the observer; the mouth, *m*, next the eye, and the dorsal edge in the distance. *a*, posterior end; *sh*, the tube enclosing *a*; *c*, the ciliated border of the disk (*s*); *b*, the larger, rigid cilia; *cv*, the contractile vesicle in the extreme distance, seen through the whole thickness of the body; *cv*^{1}, *cv*^{2}, the posterior prolongation of *cv*, in the distance; *r*, *r*^{1}, the circular and radiating branches of the nervous system; *n*, *n*^{1}, the reproductive system, extending from the right side, at *n*, posteriorly, but towards the eye at *n*^{1} (Clark).

Fig. 31.

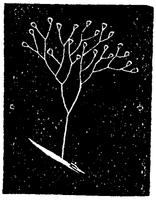
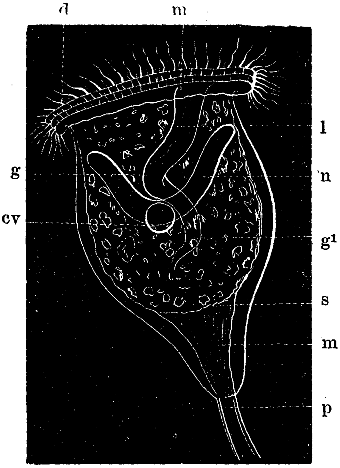


Fig. 32.



Bell-shaped Animalcule, natural size; and one enlarged.[3]

Bütschli claims to have discovered that lasso cells like those in the Hydra and jelly fishes are developed in a certain infusorium named by him Polykrikos.

The Infusoria may be divided into three groups; 1, represented by Paramecium; 2, by Vaginicola and Vorticella, and 3, by Acineta (Fig. 33, H). This latter form is not ciliated, the body is stalked and in front prolonged into slender suckers, each terminating in a mouth. At one time Stein supposed that the Vaginicola or Vorticella passed into an "Acineta-form," but Claparède disproved this and Stein retracted his opinion.

Development. The different modes of development among the Infusoria are still involved in doubt. The best observers have advanced theories that have appeared sound, and then revoked them. All agree, however, that the simplest and commonest mode of development is fission, a process analogous to the ordinary self-division of the nucleus of eggs, and the primary mode of growth in both animals and plants, not involving the idea of sex.

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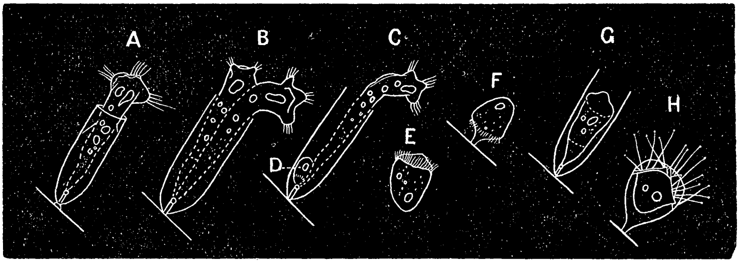
[3] Fig. 31 "*Epistylis flavicans* Ehr., a single, many-forked colony of bell animalcules, slightly magnified. Fig. 32, one of the animalcules magnified 250 diameters. *p*, the stem; *d*, the flat spiral of vibrating cilia at the edge of the disk; *ms*, the muscle; *m* to *s*, the depth of the digestive cavity; *m*, the mouth, *g*, g^1, the throat; *l*, the single vibratory lash, which projects from the depths of the throat; *cv*, the contractile vesicle: *n*, the reproductive organ" (Clark).

As a good example of *fission*, by which all Infusoria are supposed to multiply their kind, though some may at certain times reproduce from eggs, we may cite a case observed by Clark, the full account of which is given in his admirable "Mind in Nature." He observed a *Stentor polymorphus* divide in two. The first change taking place is in the contractile vesicle, which divides into two distinct vesicles. The mouth of the new Stentor is formed in the middle of the under side, first appearing as a shallow pit, around which arises a semicircle of vibratile cilia. The new mouth deepens, the throat is hollowed out; all this taking place before any external sign of division appears. But in the course of two hours the body splits asunder, and two new individuals appear, each exactly like the other.

In Vaginicola there is a modification of this simple process, which is more like true gemmation or budding, and is accompanied by a process of encysting. Our figures of the mode of development are taken from a short paper by C. J. Müller. He first traced the fission of this infusorium (Fig. 32, A), which takes place in the following manner. After the animal has withdrawn within its case, and assumed a pear-shaped form, its cilia, meanwhile, apparently lost, a conical fissure appears at the base, and soon after "a wavy line of division shows itself at the upper extremity of the animalcule;" the two fissures enlarge and meet; pulsating vesicles become active on both sides of the line of fission, and cilia begin to grow out, until at the end of an hour, two separate animals are formed, which soon afterwards appear as in Fig. 33, B.

Fig. 33.



Development of Vaginicola.

Now begins a new process; the production of a free swimming embryo. On one of the two Vaginicolas is developed "a delicate ring or band at about one-third its length from the lower extremity." Then it contracts in its cell, becomes quiet (as in Fig. 33, C, D) and from the ring or band develops a new circle of cilia, the former ones having disappeared. It then swims off as at Fig. 33, E, darting about rapidly until it attaches itself to a piece of Conferva, as at Fig. 33, F. After some hours, perhaps twenty, a fringe of cilia begins to appear on the upper end, the old ones begin to be absorbed, and the tube arises, as at Fig. 33, G, and a new Vaginicola appears. Stein had some years previous made similar observations on *Vaginicola crystallina* Ehr., and thought he had traced their further development into a form resembling Acineta (Fig. 33, H), but this proved afterwards to be a young parasitic Acineta, a suctorial Infusorian.

We have seen that Vaginicola passes through a resting stage, withdrawing into the case in which it lives, and being for a time inactive. Stein has shown that all the Vorticellinæ "at an earlier or later stage of their development become encysted, by drawing in their ciliated disk and contracting their bodies into a ball; at the same time secreting around themselves a gelatinous mass which solidifies into a firmer elastic covering." Fig. 34, G, after Stein, shows a Vorticella thus encysted. After becoming thus encysted the interior becomes homogeneous, as in Fig. 34, H. From this cyst the Vorticellæ arise directly.

Now a second mode of development, and the simplest, has been observed by Stein, *i. e.*, that of monad-like young which result from the breaking up of the cyst. While examining a cyst Stein observed that it burst, and the free contents "remained as a round, transparent limpid drop of jelly, of about the same diameter as the cyst, in which some thirty embryos, of the form of *Monas colpoda* or *Monas scintillans*, sailed about with varied and active motion, as if in a little ocean." These embryos resulted from the breaking up of the band-like nucleus. This breaking up did not take place "by successive acts of division, but in the nucleus, round disks become marked off contemporaneously, at the most distant points; whilst the intermediate substance of the nucleus becomes re-absorbed."

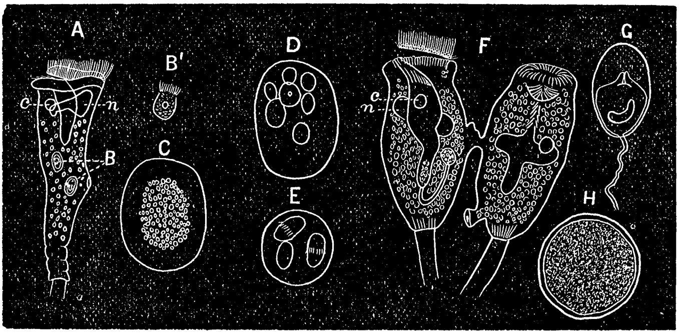
It thus seems that the Ciliata pass through a flagellate or monad condition. Stein regards the above described propagation by the change of the whole inner encysted body of a Vorticella into numerous embryos, as the equivalent of the sexual propagation of the higher animals. We also quote Stein's summary of the cycle of changes undergone by the Vorticella: "We may thus ideally arrange the different stages of development through which the *Vorticellæ* pass; the largest end their lives by becoming encysted; the whole of the contents of their bodies then passes into embryos, to which the dividing germ-nucleus first gives origin.

"The embryos become fixed, develop from their posterior extremity a stalk, which is at first not contractile, and gradually change their monad-like bodies into that of a common Vorticella.

"As soon as this has taken place, their very much smaller size only distinguishes them from the perfect Vorticellæ. Even in this imperfect condition they frequently multiply by continual division and in a subordinate degree by external gemmation. This power of multiplication in the imperfect state, however, is one of the most certain criteria that we have to do with an alternation of generations. * * * * Finally, the last generation become encysted, not to re-awake to an independent existence, but to break up into a swarm of embryos."

Let us now look at the development of *Epistylis plicatilis* as studied by Claparède. Fig. 34, A, represents an individual containing several embryos (B) and opposite the lower one on the right side is a projection, through which the embryo at B′ has passed out. The specimen figured at B′ is a fair example of the embryos of species belonging to six families of Infusoria, and

Fig. 34.



Development of Epistylis.

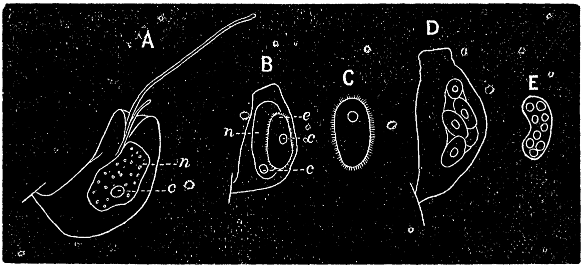
may, perhaps, serve as a typical example of most Infusoria at the time of birth. This young stage may, then, be contrasted with the embryos of the Flagellata, which are of a much simpler form, resembling the zoospores of the algæ and lower Protozoa.

The embryos of the Infusoria arise from the nucleus, which corresponds to the ovary of the higher animals. The nucleus is a curved, oblong, oval body, represented in Figs. 34, A, *n;* 35, E. When the Epistylis is about to reproduce its young, the nucleus sends off a portion which enlarges until it assumes the appearance indicated by Fig. 34, C. It has become round, and contains a central, granular mass, from which the embryos arise. At Fig. 34, D, is a globular mass, detached from the nucleus, and containing several embryos in the first state of development. Fig. 34, E, represents the embryos provided with a circle of cilia, and nearly ready to swim about freely. Claparède did not watch their farther development, but thought it probable that they grew directly into the Epistylis form.

What is the meaning of conjugation in the Infusoria is not clearly understood. Whether it is analogous to sexual union is not certainly known, but it is now thought by Balbiani that the smaller individuals found conjugating with the larger are males, and he even thinks that some Infusoria contain spermatozoa. Fig. 34 represents an Epistylis conjugating, each one provided with two buds; the bud of the individual on the left is conjugated with that of the individual on the right hand. Epistylis also passes through encysted stages as indicated at Fig. 34, G and H.

The same mode of development was observed by Claparède in a parasite of the Epistylis, *i. e.*, *Urnula epistylidis* (Fig. 35), which, besides reproducing by fission, also produces ciliated

Fig. 35.



Development of Urnula.

young. Fig. 35, B, *e*, represents the ciliated young within the body of the parent, B; Fig. 35, C, the free swimming ciliated young. In another specimen Claparède observed the interior of the body subdivide into several masses, as at Fig. 35, D. These masses increase in size and become filled with a number of small corpuscles, with active movements, which finally press through the walls of the Urnula. These are probably spermatozoa, as Stein considers Urnula as the male of Epistylis, contrary to the opinion of Claparède, who regarded it as a Rhizopod, though its ciliated young is, in the light of later studies, sufficient to prove that it is a ciliate infusorian.

As to the sexuality of the Infusoria, Balbiani has advanced the idea that they are in reality hermaphrodite, the nucleus representing the ovary, and the nucleolus the testis, the latter producing bodies which he regards as spermatozoa. Claparède regards this view as well founded, as it had already been suggested by himself, Lieberkühn, J. Müller and Stein that certain Infusoria contained spermatic particles, found not only in the nucleolus, but also in the nucleus, into which they had penetrated from the nucleolus. This has been observed in Paramecium, where, as Claparède quotes as Stein's opinion, that "Fecundation having been accomplished, these zoosperms disappear, and the nucleus then divides in a manner comparable to the segmentation of the egg into a certain number of segments, or reproductive bodies, destined each to give rise to an embryo. The Infusoria, then," adds Claparède, "are androgynous."

It appears, also from the observations of Balbiani, that the Infusoria, as Stentor, Paramecium, Vorticella, etc., have true eggs, each egg consisting of "two hollow membranous spheres, the smaller being enclosed within the other, and separated from it by a considerable interval." The smaller vescicle he regards as the germinal vesicle, and the larger as the vitelline membrane. After the fecundation, "at the end of four or five days, the development of the eggs is complete, and each, with the aid of reagents, displays in a very distinct manner its characteristic elements, namely, vitelline membrane, vitellus, germ-vesicle and germ-spot." Bütschli, however, it should be stated, denies that Infusoria produce spermatozoids which fertilize the nucleus. As to the development of the Acinetæ, self-fission is in them very are, while conjugation is very frequent.

There are, then, two modes of development among the Infusoria (Ciliata):—

1. By fission.
2. By production of internal ciliated embryo arising from eggs.

We have, then, for the first time among the Protozoa, if the observations of Balbiani be correct (though this is denied by good observers), truly sexual animals, producing true eggs and spermatic particles. The same animal reproduces both by fission and by the production of ciliated embryos. Most of them before producing embryos undergo fission. This is comparable to the alternation of generations among the Hydroids, Aphides, etc.

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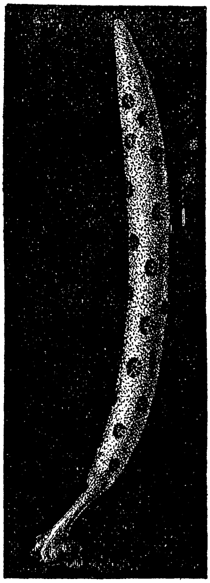
VIII. THE SPONGIÆ (PORIFERA).

We now come to animals whose bodies are composed of numerous cells, and which produce true eggs, sometimes even with a thin calcareous shell, and genuine sperm cells. The embryo sponge arises from eggs which undergo a total segmentation of the yolk. The free swimming larva later in its life becomes fixed, loses its external cilia, but retains its cellular walls, now composed of two layers, which are supported by silicious or calcareous needles or spicules developed in the inner layer.

To regard such an organism as a Protozoan, or even to compare it with a compound Radiolarian such as Sphærozoum, with its silicious spicules and aggregations of one-celled organisms, would not seem warranted. We have, in fact, in the light of the anatomical investigations of Lieberkühn, Carter and Clark, and the combined anatomical and embryological studies of Hæckel, Metschnikoff and Carter, no grounds for leaving them among the Protozoa. Indeed, one of the most striking illustrations of the value of the knowledge of the early history of an organism is afforded by the embryology of the sponge. Hæckel's discovery that the larval sponge is a planula, though not homologous with the embryo polype or jelly-fish, enables the naturalist to at once decide that the sponge is not a Protozoan, but belongs to a type only less highly organized than the lower polypes, and with more analogy to the Radiates than the Protozoa.

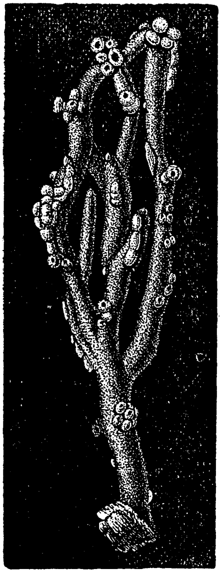
If, under the guidance of the results of the studies of Lieberkühn, Carter, Clark, and particularly of Hæckel and Metschnikoff, we examine the structure of a sponge, we shall find that in its simplest form it is a hollow, vertical cylinder, fastened by its base, with the mouth opening upwards from a central gastro-vascular cavity, with ciliated epithelial cells lining the cavity, and possessing a surprising degree of individuality. There usually are several mouths, and the cavity usually opens into a labyrinth of chambers connected by passages through the cellular tissue; these round chambers being lined with ciliated epithelial cells. This

Fig. 36.



Axinella polypoides.

Fig. 37.

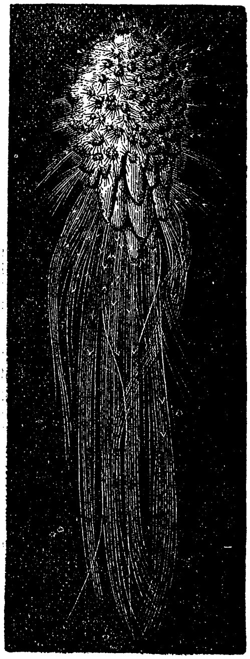


Axinella, with a parasitic polype, 2-3 natural size. After Schmidt.

body is supported by a basket-work of interlaced needles of silica or lime, developed in the inner layer of cells of the larva.

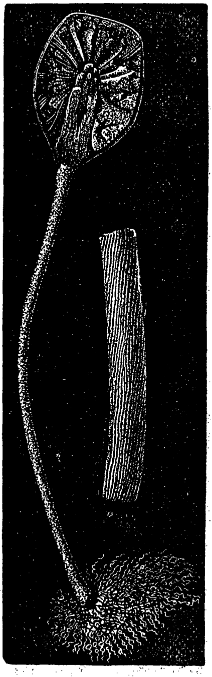
Such, in brief, is the sponge. Does the fact that in the simplest, immature forms, we have quite a regular body-wall and a single cavity, compel us to range the sponges side by side and in he same natural division with the polypes and jelly-fishes, in the typical forms of which the central cavity acts as a true stomach and the outlet surrounded with tentacles acts as a mouth? Metschnikoff has shown that it would seem to be a violation of the existing principles of classification to place together animals so unlike. The sponges apparently represent a class lower than, but possibly equivalent, systematically, to the polypes and jelly-fishes.

Fig. 38.



Tethilla polyura. After Schmidt.

Fig. 40.

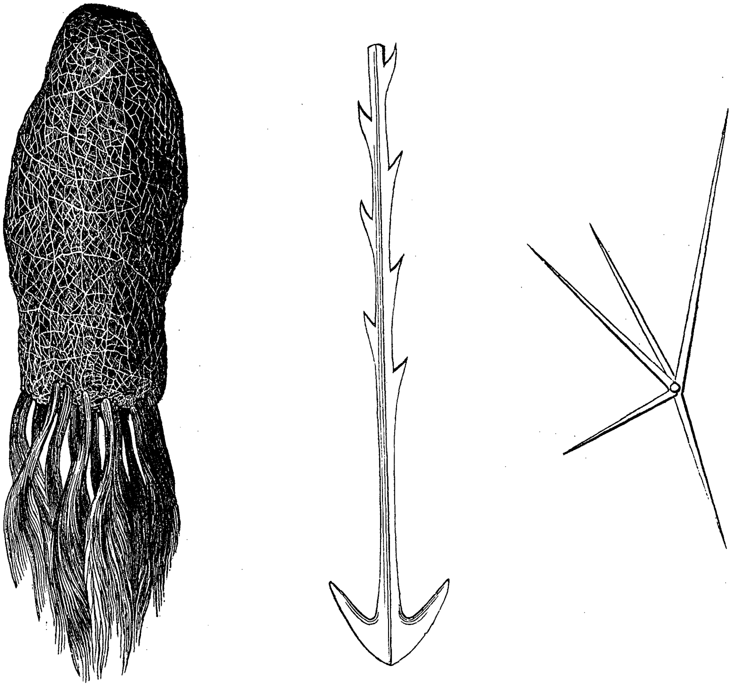


Hyalonema boreale. Nat. size; with part of stem enlarged. After Lovén.

Currents of water, created by the cilia and bearing along particles of food, enter through the system of mouths, and when the food is absorbed by the cells of the inner lining, they pass out through the larger openings. Both the larger and smaller "mouths" are capable of opening and closing.

The eggs and sperm cells are scattered at irregular intervals among the cells composing the body-walls; the spermatozoa are in some species developed in "mother" cells, as in many of the higher animals.

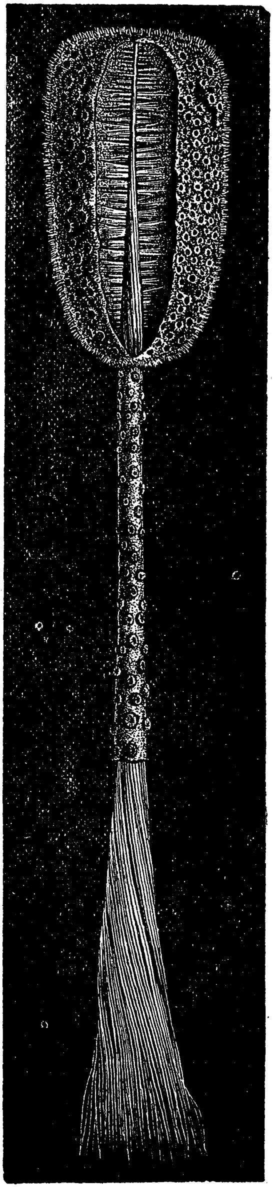
Fig. 39.



Pheronema Annæ and Spicules. After Leidy.

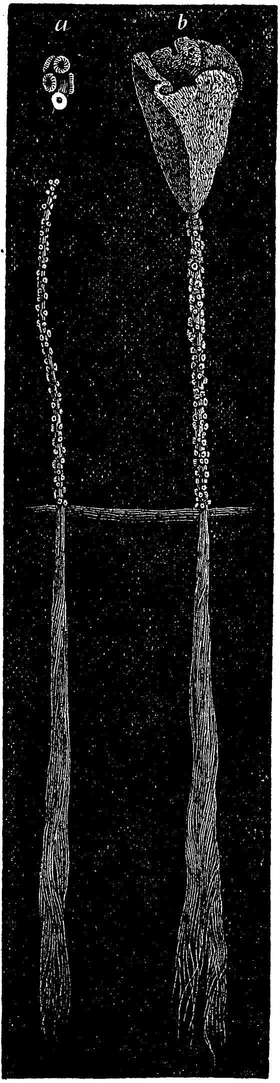
The sponges are by Hæckel regarded as closely allied to the Hydroid polypes, members of the Cœlenterates, a division formed by Leuckart, including the polypes and acalephs. His reasons are based on the fact that the sponges are made up of two layers of cells (ectoderm and entoderm, or outer and inner layer) surrounding a central cavity, and that both reproduce by eggs and spermatozoa, and pass through a "planula" stage.

Fig. 41.



Hyalonema Sieboldii ($\frac{1}{3}$ nat. size). After Schulze.

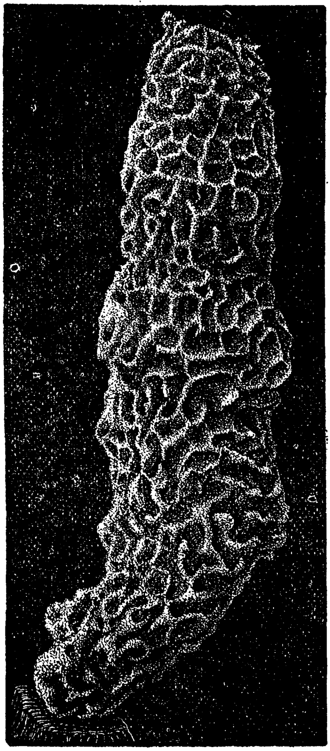
Fig. 42.



Hyalonema with parasitic polypes, embedded half its length in the mud. After Gray.

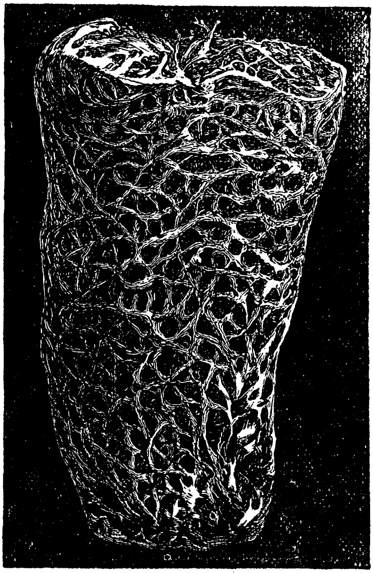
Gegenbaur and some English naturalists have endorsed this view. Hæckel goes so far as to state that the only character excluding the sponges from the Cœlenterates is the want of lasso cells,[4] but we have seen that the true Infusoria possess them.

Fig. 43.



Tuba labyrinthiformis, $\frac{1}{3}$ natural size. After Lütken.

Fig. 44.



Corbitella, $\frac{2}{3}$ natural size. After Lütken.

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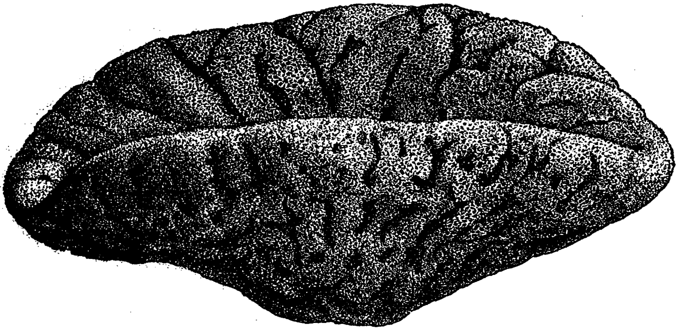
[4] Eimer claims to have found true lasso cells in Reniera, a sponge observed by him at Capri; but Carter attributes their presence to a parasitic polype which he detected in this sponge. Eimer on other grounds claims that he has discovered a sponge which affords a passage into the Hydroids. "In an Esperia, in another silicious sponge allied to Myxilla, and in a horny sponge, the surface is studded with small chitinous tubes, which are external prolongations of a similar investment of the whole channel-system, becoming, however, more delicate below, and finally passing into a sarcode-like condition; each of these tubes is inhabited by a retractile, sac-like body, provided with ectoderm, a muscular layer, and entoderm, with thread cells, and with 6–12 long, unbranched tentacles, with cilia and thread cells; below, they pass successively into the common sponge-substance, and generally lie four in each channel, each, however, with

But Metschnikoff has shown that there is no true homology between the sponges and Radiates.

The sponges are divided into (1) the *Myxospongiæ*, represented by Halisarca; (2) the *Fibrospongiæ*, or the silicious sponges, represented by Axinella (Fig. 36, *A. polypoides;* 37, another species of Axinella), the fresh water Spongilla; Thethya, Tethilla (Fig. 38 *T. polyura*); Pheronema (Fig. 39, *P. Annæ* and spines); the glass sponges, such as Hyalonema (*H. boreale*, Fig. 40, from the Arctic Ocean; Fig. 41, *H. Sieboldii;* Fig. 42, another Hyalonema, anchored in the mud by its silicious threads) the Venus flower basket, or *Euplectella aspergillum* from the Philippines; the Tuba (Fig. 43, *T. labyrinthiformis*) from the West Indies; the Corbitella from the Moluccas (Fig. 44); and Dactyocalyx (Fig. 45, *D. pumicea*[5]) from the West Indies. The third division of sponges comprises the calcareous sponges (*Calcispongiæ*) represented by the Sycon (*Sycandra ciliata*, Fig. 46), a common little white sponge found on our shores, and in the North Atlantic generally.

Fig. 45.



Dactyocalyx pumicea. After Lütken.

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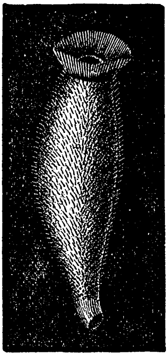
its own special chitinous tube. In other sponges (Renieræ) these polypoids were found in a lower stage of evolution, with short or absent tentacles, thread-cells present or wanting, no muscular layer, chitinous investment sometimes strongly developed, annular and projecting—in other instances reduced to a delicate, almost sarcode-like membrane, or almost totally wanting. The idea of parasitism is, according to the author, quite out of the question; the 'polypoids' he constantly regards as the true nutritive zooids of the sponge, and the sponges in which they occur in a more rudimentary shape as intermediate forms, leading to the great majority of sponges without nutritive zooids of any kind." Lütken in Zoological Record for 1872. London, 1874.

[5] This and Figs. 36–38, 40–46, were kindly loaned me by Dr. C. F. Lütken, of the Royal Zoological Museum at Copenhagen. They are from the Tidsskrift for Populære Fremstillinger af Naturvidenskaben. 1871.

Development. Lieberkühn made the astonishing discovery, confirmed by Hæckel, that sponges were really hermaphrodite animals reproducing by eggs and sperm cells developed in the same individual sponge. Hæckel showed that they were probably developed from the inner (endodermal) layer of cells forming the body, being simply modifications of these endodermal cells, much as the eggs of the higher animals are modified epithelial cells. Fig. 47, from Hæckel, shows one of these cells (of *Sycortes quadrangulata*) with several spermatozoa mingling their protoplasmic contents with the protoplasm of the egg itself.

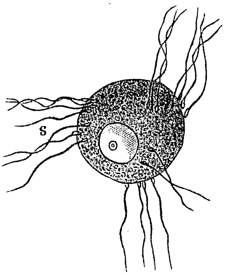
Fig. 46.



Sycandra ciliata, a calcareous sponge enlarged. After Schmidt.

The endodermal cell transforms into an egg, according to Hæckel, in the following manner. At first provided with a "collar" and flagellum much as in the Codosiga figured on page 42, it begins to draw these in until they disappear; then a nucleus (nucleolinus) appears within the nucleolus of the cell. The egg soon becomes detached from the body wall, and moves about, sometimes penetrating into the exoderm, or "emigrating, in the oviparous species, from the 'stomach' to be fecundated abroad."

Fig. 47.

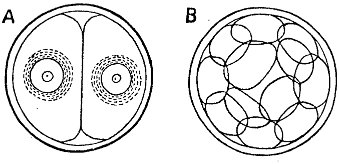


Fusion of spermatic particles with egg of sponge. After Hæckel.

"The spermatozoa are apparently developed through repeated divisions of modified endodermal cells; the 'head' is formed by the 'nucleus,' the tail by the protoplasm of the minute sperm-cells."

After fecundation of the egg, it begins to undergo self-division, splitting into two, four, eight, sixteen, etc., nucleolinated cells (Fig 48, total segmentation of eggs of Halisarca), the process being exactly as in the eggs of nearly all the higher animals including man. This stage of segmentation, like the mulberry mass of the egg after segmentation in the higher animals, Hæckel terms the Morula stage (from its likeness to the mulberry, Morus; see Fig. 48, after Carter). The cells of the

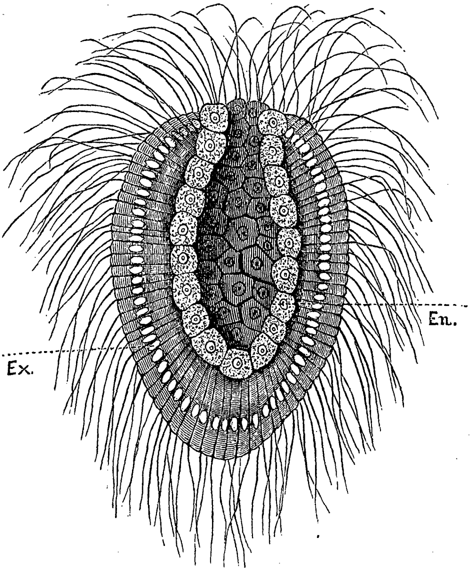
Fig. 48.



Segmentation of egg of sponge.

Morula afterwards become separated into two kinds, a few remaining round, the majority becoming long and prismatic, and provided each with a cilium (flagellum), by means of which it swims about and looks like a "planula" or larval jelly-fish. This stage Hæckel consequently calls the "Planula" stage. The next step is the formation of a "stomach" or internal cavity in the body of the ciliated larva. This stage Hæckel calls "Gastrula." Fig. 49, from Hæckel, represents the gastrula of *Leuculmis echinus*, as seen in optical section, the outer layer (ectoderm) being composed of long prismatic, nucleated cells (*ex*) provided with a lash, while the cells (*en*) of the lining (endoderm) of the cavity are much larger and rounder.[6] After swimming about for a time it becomes fixed by the end of the body to some object, the cavity finally opening out by a mouth. The external cilia now disappear, and others become developed in the cells lining the interior of the cavity.[7] Afterwards the true sponge char-

Fig. 49.



Larva of a Sponge.

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[6] Metschnikoff shows that this "entoderm" is really an invaginated portion of Hæckel's "ectoderm."

[7] Metschnikoff observed on the contrary that the ciliated external cells are with drawn in the process of growth and line the cavity.

acter of the organism is revealed. The body-wall becomes perforated with pores, which open into the general cavity of the body, while currents of water are maintained by means of the cilia, and flow out through the so-called mouth. This is the "Protospongia" state, and when spicules of silex or lime are developed to strengthen the walls of the body, the young sponge is termed by Hæckel, the "Olynthus."

Thus following the course of development as Hæckel supposed to be the case with the calcareous sponges, for he, as Metschnikoff remarks, did not actually observe the stages after the formation of the ciliated larva we obtain a very clear idea of the typical structure of the sponge. I cannot do better than employ the condensed account of the discoveries of Hæckel given by Dr. Lütken in the "Zoological Record" for 1872, with a few corrections taken from Metschnikoff's paper. The Olynthus, the simplest type of the sponge, is a "cylindrical, clavate or pyriform, etc., tube, closed at the extremity by which it is affixed, commonly open by a 'mouth' at the other; the body-wall, enclosing the 'gastric' cavity, is a thin membrane composed of the two layers named above—the '*syncytium*' or exoderm [Metschnikoff's inner layer] a mass of sarcodine with nuclei, the cells of which are so completely fused together that the original cellular structure cannot be made visible through any chemical reaction; if torn mechanically, the fragments will, whether containing one or more or no nuclei, take the shape of Amœbæ and walk about. In this layer[8] the spicula are developed, chiefly of three types—simple, 3-radiate and 4-radiate, anchor-shaped spicula are rare (*Syculmis synapta*, anchoring the animal in the mud bottom); the stellate spicula sometimes occurring are foreign bodies, belonging originally to Didemnia (Ascidiæ). The spicula are invested with a delicate sheath of condensed sarcodine; they contain an axial filament, and are composed of concentric layers, like the silicious spicula; chemically they are composed partly of Co_2, CaO, partly of an organic substance ('spiculin'). The endodermal cells are, like certain flagellate Infusoria, provided with a collar and flagellum; they contain a 'nucleus' (with 'nucleolus'), and often one or two contractile 'vacuola' (water drops); though without 'mouth,' they both 'drink' and 'eat,' or receive into their interior, not only fluid, but also minutely diffused solid matter (*e. g.*, carmine), probably through the soft exoplasm between the collar and flagellum. Liberated artificially, they also assume amœboid shapes and motions. On the endodermal cells devolve the whole of the nutritive (digestive, respiratory and secretory) functions; and there can be little doubt that both eggs and spermatozoa are modified endodermal cells."

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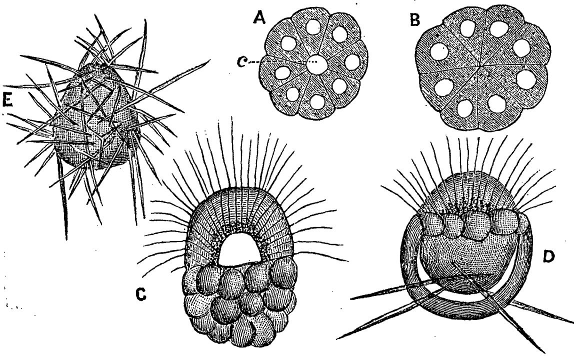
[8] Metschnikoff shows that the spicules really arise from the inner layer.

Hæckel did not observe the development of the larva, his gastrula, into the young sponge. This gap has been filled by Metschnikoff. He observed the course of development in *Sycon ciliatum* (Fig. 50) from the segmentation of the yolk, through the larval state, up to the time when the sponge is fixed and the spicules are well developed; in fact, through nearly every important stage in its life. By making a section through the sponge he found eggs and embryos in different stages of development in springtime. The total segmentation occurred as Hæckel describes. Metschnikoff, however, observed that a small "segmentation-cavity" appeared in the egg (Fig. 50, A, *c*) which soon disappeared (Fig. 50, B). As a result of the process of division, a roundish embryo appears, which is made up of a large number of small cells. He was unable to study the mode of origin of the germ-layers. The free-swimming larva (Fig. 50, C) is an oval body, made up of two sorts of cells: those which are small, long and ciliated, and certain large round ones, much fewer in number. The first form a

Fig. 50.



Sycon ciliatum.

sort of arch, with a hollow in the middle, surrounding which a large number of very fine brown pigment corpuscles are collected. The next change of importance is the disappearance of the cavity, the upper or ciliated half of the body being much reduced in size. Then the large round cells of the hinder part are united into a compact mass, leaving only a single row. The ciliated cells are gradually withdrawn into the body cavity. Fig. 50, D, shows this process going on. At this period also the larva becomes sessile, and now begins the formation of the sponge spicules, which develop from the non-ciliated round cells. Metschnikoff calls attention to the fact that at this early stage the Sycon passes through a phase which is persistent in the genus Sycyssa. The layer of ciliated cells are gradually withdrawn into the body cavity, until a small opening is left, surrounded with a circle of cilia. These cilia finally disappear, and a few more spicules grow out, and meanwhile the opening disappears. In the next stage (represented at D) a considerable (gastrovascular) cavity appears, which may be seen through the body-walls. At this time, by soaking the specimen in acetic acid, the body of the sponge was seen to consist of two layers, the inner layer of ciliated cells forming a closed sac, enveloped in the spicule-generating layer (representing the entoderm). At this time no mouth-opening was formed, though three-pointed spicules had appeared.

It results from Metschnikoff's observations that the body of the larval sponge is composed of two primary germ-layers, an "entoderm" and "ectoderm," the two germ layers about which we shall hear much more hereafter.

The observations of Carter, made on several additional species both of silicious and calcareous sponges, confirm the results of Metschnikoff as to the later history of the larval sponge, and those of Hæckel as to the mode of segmentation of the egg. Our Fig. 48, A (copied from Carter), shows the total segmentation of the yolk in *Halisarca lobularis* into two portions ; these portions farther subdivide, as at Fig. 48, B, until an immense number of small embryonic cells are produced.

Carter observes that the embryos may be found at all seasons, from March through the summer. These observations are not difficult to follow out. We have, by tearing apart a species of Sycandra (or Sycon) perhaps *S. ciliata*, which grows on a Ptilota, found the planula much as figured by Hæckel, Metschnikoff and

Carter, and any one can with patience and care observe the life history of the marine sponges.

It seems, then, that the life history of the sponges consists of the following stages :—

1. Fertilization of a true egg by genuine spermatozoa; both eggs and sperm cells arising from the inner germ-layer.

2. Total segmentation of the yolk, or protoplasmic contents of the egg.

3. A ciliated embryo.

4. A free swimming "planula"-like larva, with two germ-layers, not, however, originating as in the true planula of the acalephs. The planula becomes sessile, spicules are developed in the hinder end of the body, afterwards a gastro-vascular cavity appears, constituting the

5. Gastrula stage.

6. A mouth and side openings appear and the true sponge characters are assumed.

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REVIEWS AND BOOK NOTICES.

The Spiders of France.[1]—Mr. E. Simon has just published the first part of a monograph of the Arachnida of France, forming an octavo volume of two hundred and seventy pages, with three plates. Beginning with the Araneæ he describes the Epeiridæ, Uloboridæ, Dictynidæ, Enyoidæ and Pholcidæ. This arrangement is not meant for a natural one, but has been adopted because the work on these families was first finished by the author. The introduction is promised in a future part, but the present volume begins with a short review of the principal descriptive works on

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[1] Les Arachnides de France. Par E. Simon, Tome 1, Paris, 1874, with 3 plates 8vo. pp. 270.